

Interaction Region Design for eRHIC

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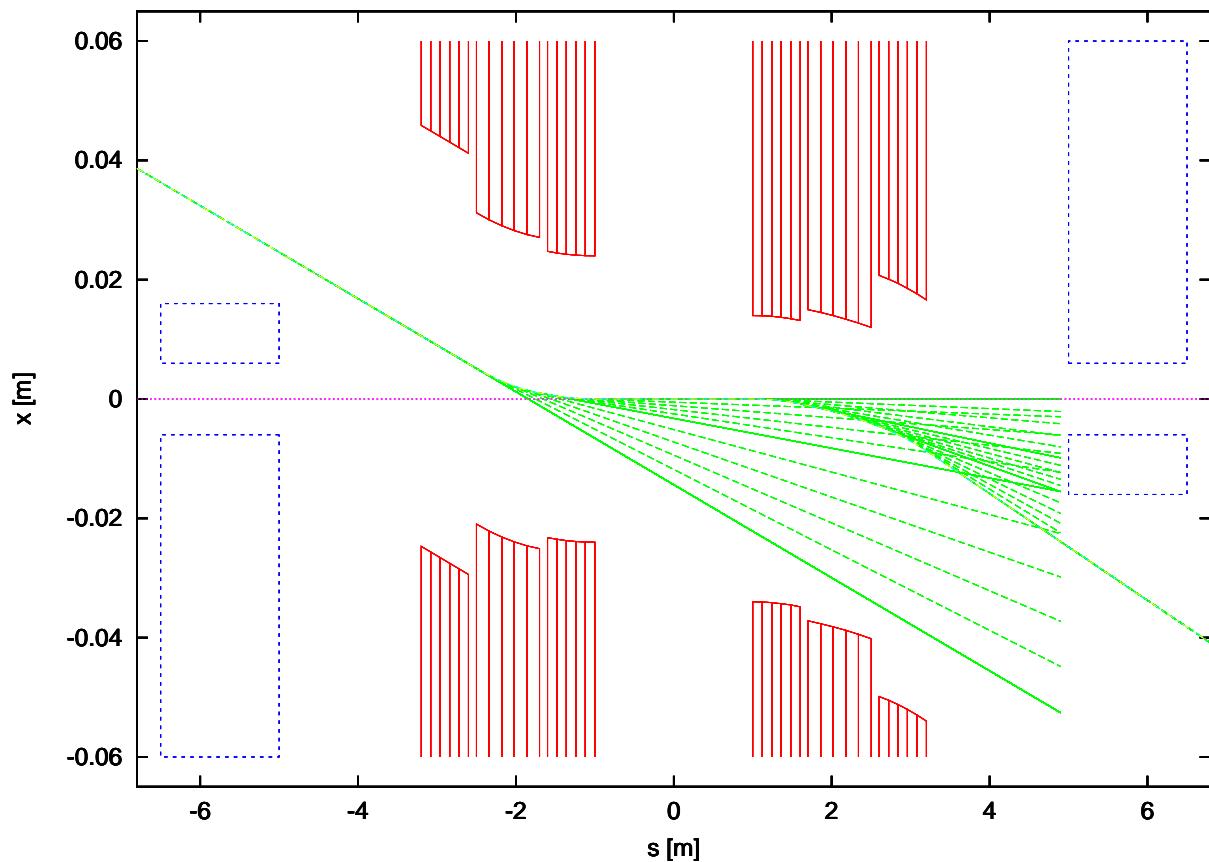
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eRHIC

- \vec{e} - \vec{p} / \vec{e} - A collider
- 10 GeV \vec{e} vs. 250 GeV \vec{p} , or 100 GeV/n Au
- flexible beam energies
- luminosity goal ($\vec{e} - \vec{p}$): $\approx 10^{33} \text{ cm}^{-2}\text{sec}^{-1}$
- two approaches: ring-ring and linac-ring

Interaction region has to:

- focus beams to small spot sizes to maximize luminosity
- separate beams
- accomodate synchrotron radiation generated by beam separation



Beam separation by a crossing angle

Required crossing angle to provide separation without additional dipoles:

$$> 5 \text{ mrad}$$

Large crossing angle **reduces luminosity by factor ≈ 5** due to long hadron bunches

Cure: Crab Crossing

(= rotating hadron bunches into the direction of the electron orbit)

Developed for KEKB (8 GeV electrons), but not installed

Crab Crossing

Required transverse deflecting voltage
(according to KEKB design report):

$$V_{\perp} = \frac{cE \tan \Theta}{e\omega_{\text{RF}} \sqrt{\beta^* \beta_{\text{crab}}}}$$

For:

250 GeV protons (or 100 GeV gold ions),

$\Theta = 6 \text{ mrad}$,

$\beta_{\text{crab}} = 400 \text{ m}$,

and $\omega_{\text{RF}} = 2\pi \cdot 200 \text{ MHz}$,

this yields

$$V_{\perp} = 36 \text{ MV}$$

For comparison: RHIC RF voltage is 2 MV

IR Design Constraints

- zero crossing angle
- proton septum quadrupole starts at 5 m
 - keep horizontal beam sizes at 5 m small to minimize required electron separation angle
- $\sigma_{x,h} \propto 1/\sqrt{\beta_{x,h}^*}$
 - lower limit on $\beta_{x,h}^*$
- $\sigma_{x,e} \propto \sqrt{\epsilon_{x,e}}$, but smaller $\epsilon_{x,e}$ requires larger $\beta_{x,e}^*$ to match beam sizes
 - larger beam-beam parameter
 - luminosity limitation for ring-ring design
- beam-beam parameter limit:
 $\xi_e = 0.05, \xi_h = 0.007$

IR parameters for 10 GeV e on 250 GeV p

	ring-ring	linac-ring	luminosity ratio
	$\mathcal{L}_{l-r}/\mathcal{L}_{r-r}$		
ϵ_h [nm]	9.5	9.5	
ϵ_e (x/y) [nm]	53/9.5	2.5/2.5	
β_h (x/y) [m]	1.08/0.27	0.27/0.27	
β_e (x/y) [m]	0.19/0.27	0.92/0.92	
σ^* (x/y) [μm]	100/50	50/50	2
N_e/bunch [10^{11}]	1.0	1.0	
N_p/bunch [10^{11}]	1.0	1.0...2.0	1...2
ξ_h (x/y)	0.007/0.0035	0.007/0.0035	
ξ_e (x/y)	0.022/0.08		
\mathcal{L} [$10^{33} \text{ cm}^{-2}\text{sec}^{-1}$]	0.44	1.0...2.0	2...4

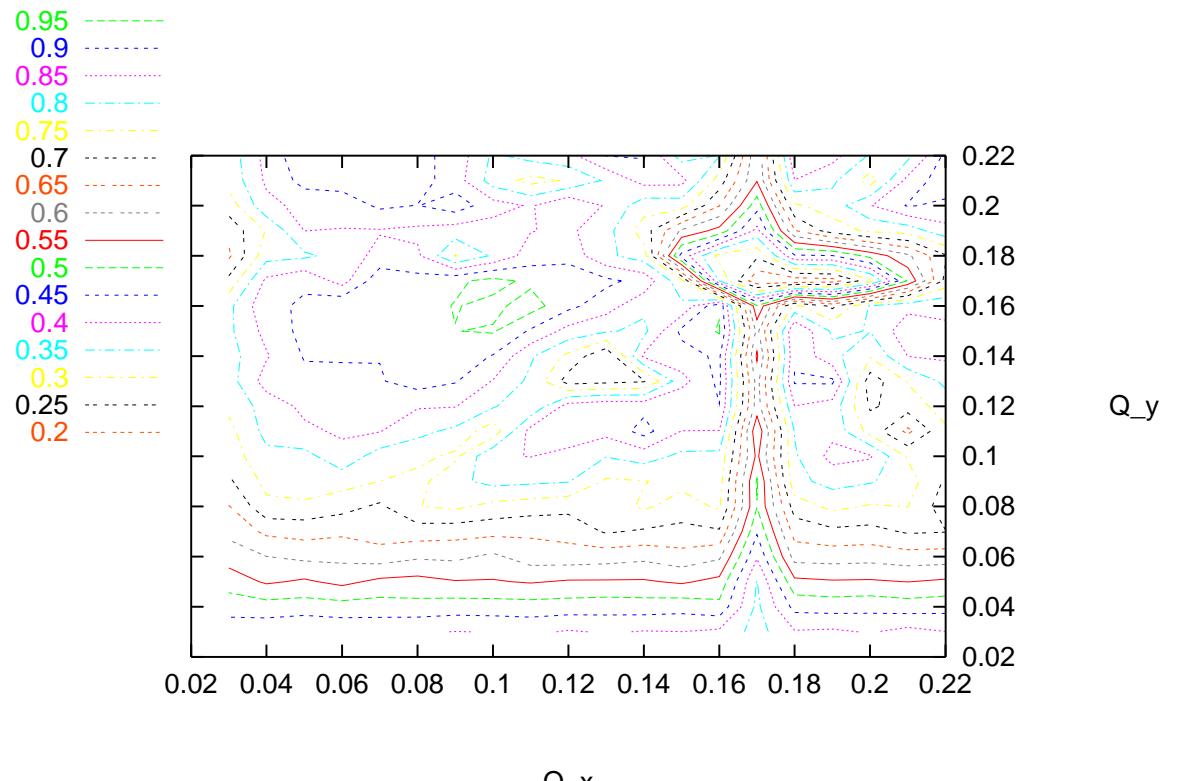
Beam-beam contour plot

Simulation of beam-beam effect in eRHIC electron ring.

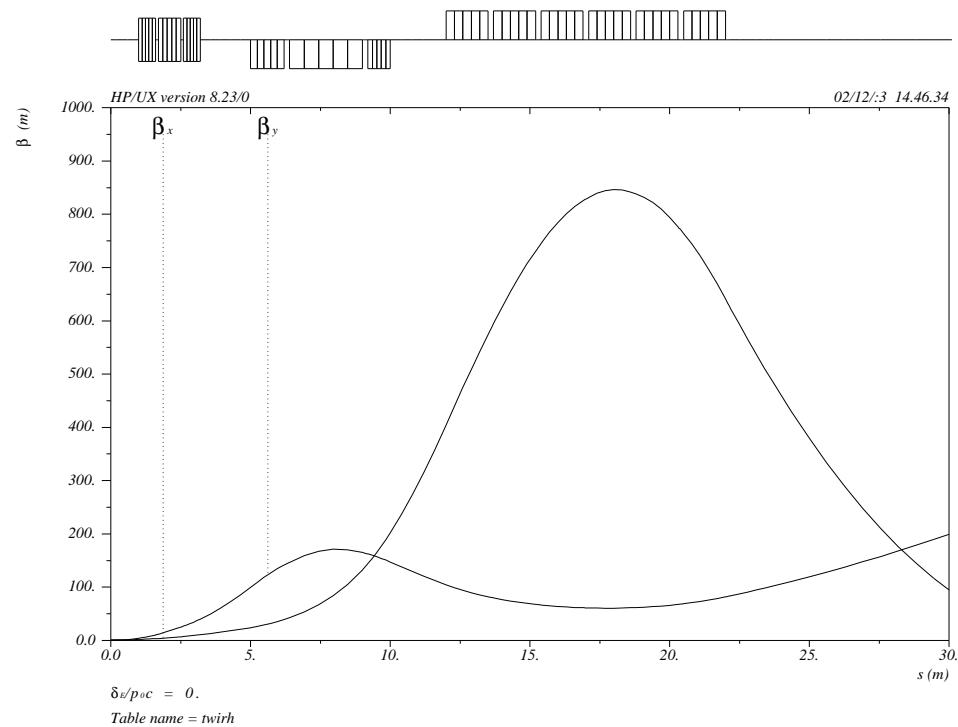
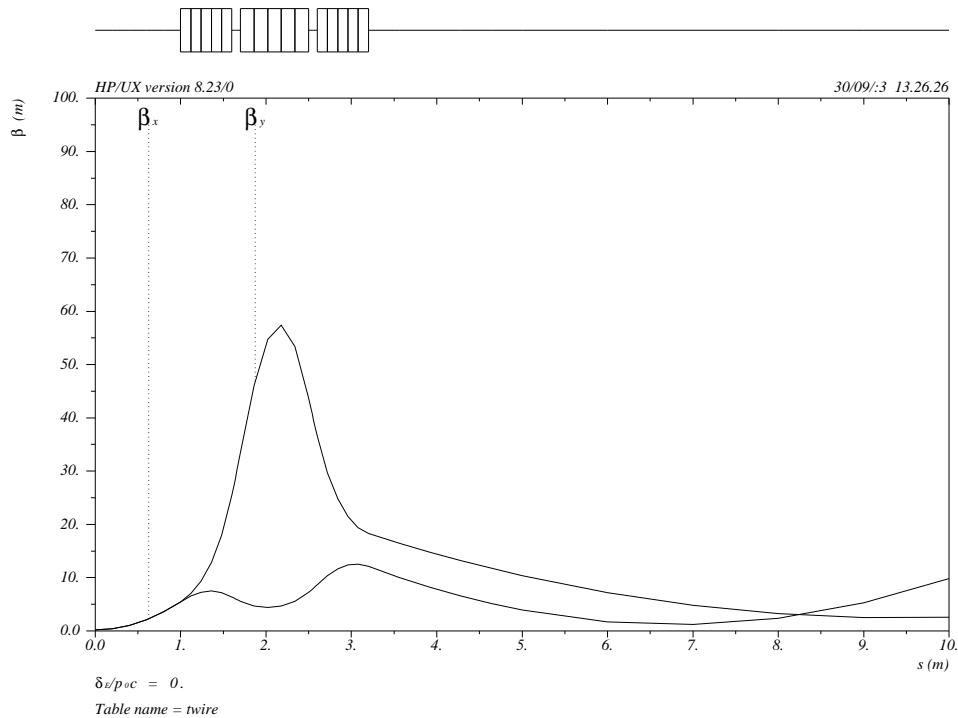
- Perfect, linear lattice
- 4D (no synchrotron motion, zero bunch length)

Contours show

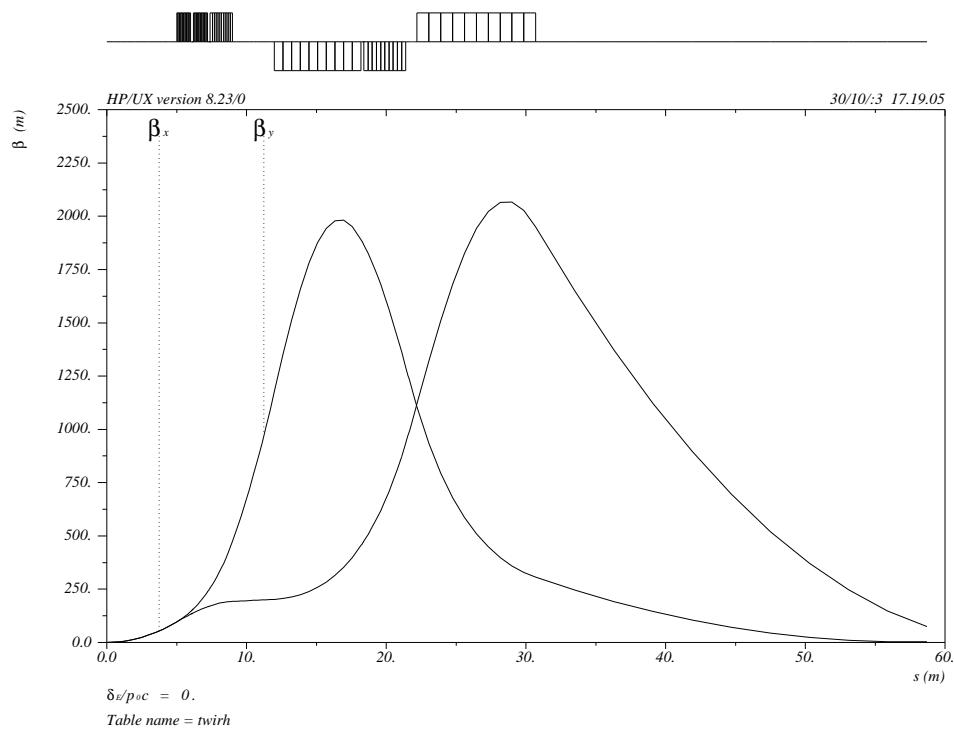
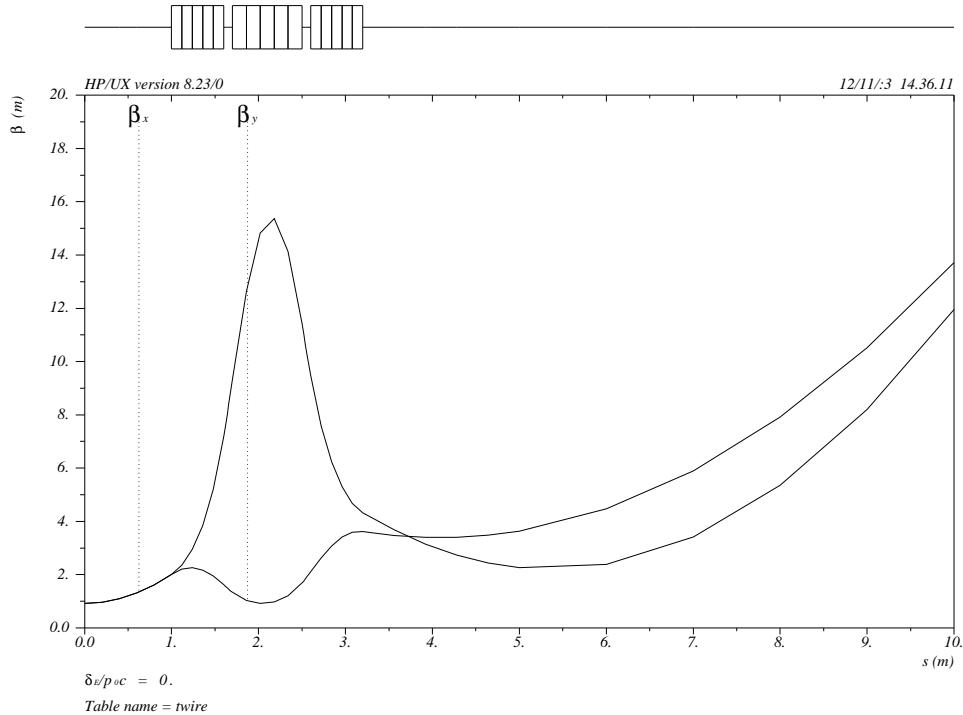
$$\mathcal{L}/\mathcal{L}_{\text{nominal}}, \text{ with } \mathcal{L}_{\text{nominal}} = 4.4 \cdot 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$$



Ring-ring IR lattice



Linac-ring IR lattice



Conclusion

- IR design solutions for both ring-ring and linac-ring option of eRHIC exist.
- Linac-ring option provides at least 2 times more luminosity for $10 \text{ GeV } e$ on $250 \text{ GeV } p$. This factor becomes even larger for lower energies, where the hadron current for ring-ring has to be significantly reduced to keep electron beam-beam parameter below its limit.
- Linac-ring option cannot provide positrons.

What is most important, higher luminosity or positron option?

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